GEO-SEQ: Three Years of Progress 2000 - 2003

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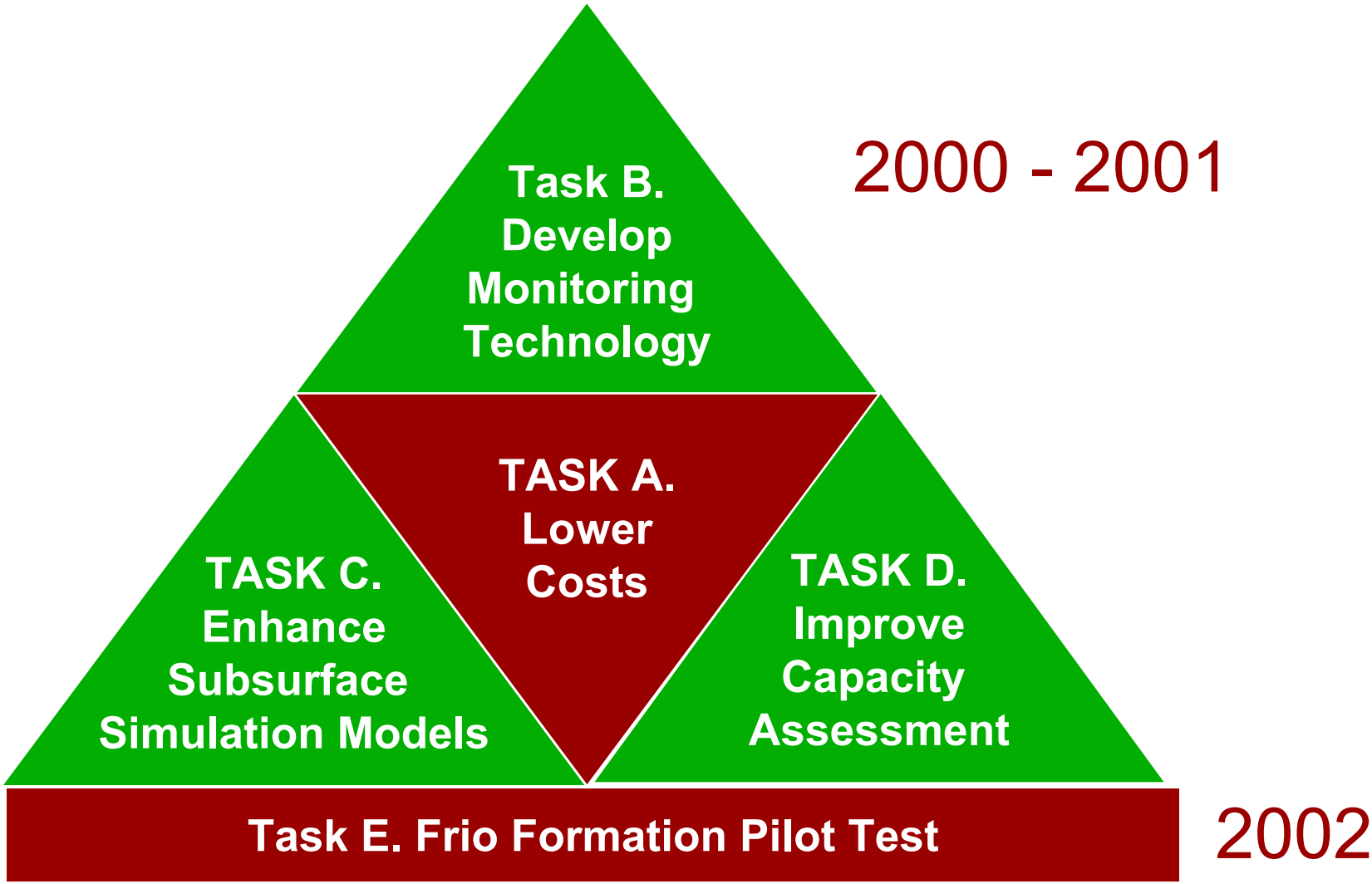
GEO-SEQ: A Public-Private Partnership

- **Funded by DOE Fossil Energy**
- **Three DOE National Laboratories**
  - **Lawrence Berkeley National Laboratory**
  - **Oak Ridge National Laboratory**
  - **Lawrence Livermore National Laboratory**
- **Three research organizations**
  - **Stanford University**
  - **Texas Bureau of Economic Geology**
  - **Alberta Research Council**
- **Four industry partners**
  - **ChevronTexaco, BP-Amoco, Encana, Statoil**

Five Coordinated and Interrelated Applied Research Tasks



2000 - 2001

2002

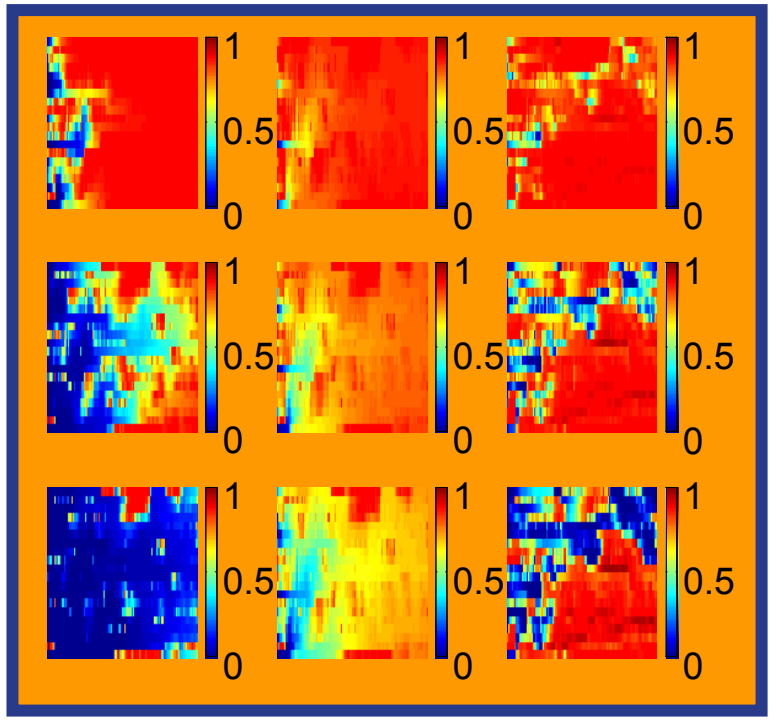
Increasing CO_2 Storage Efficiency in Oil Reservoirs

Lynn Orr and Tony Kvoseck

- Stanford University

Methods to Co-Optimize EOR and Sequestration

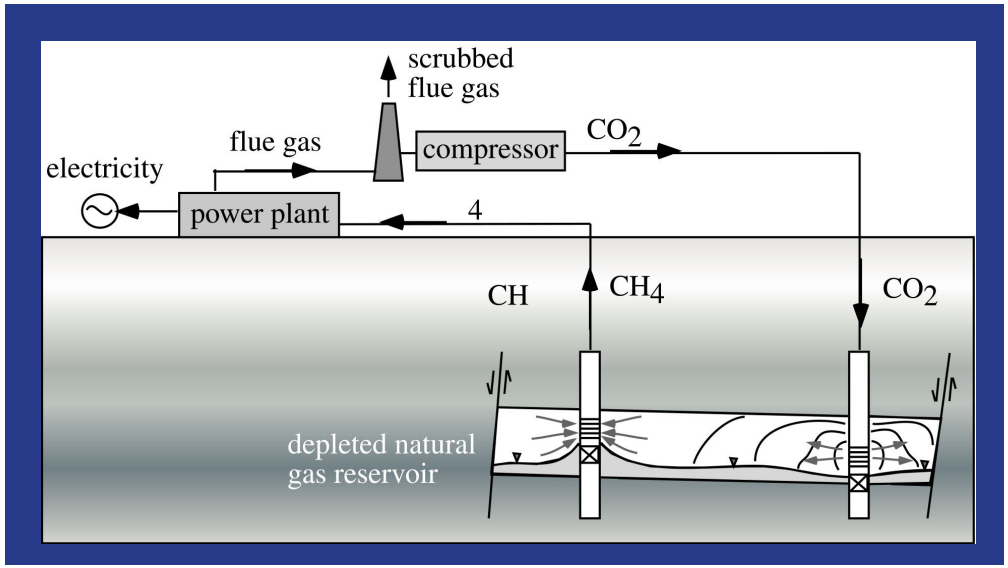
- Selection criteria
- Streamline compositional simulation
- Production and injection strategy



Influence of heterogeneity and gravity on sweep efficiency

Carbon Sequestration with Enhanced Gas Recovery (CSEGR)

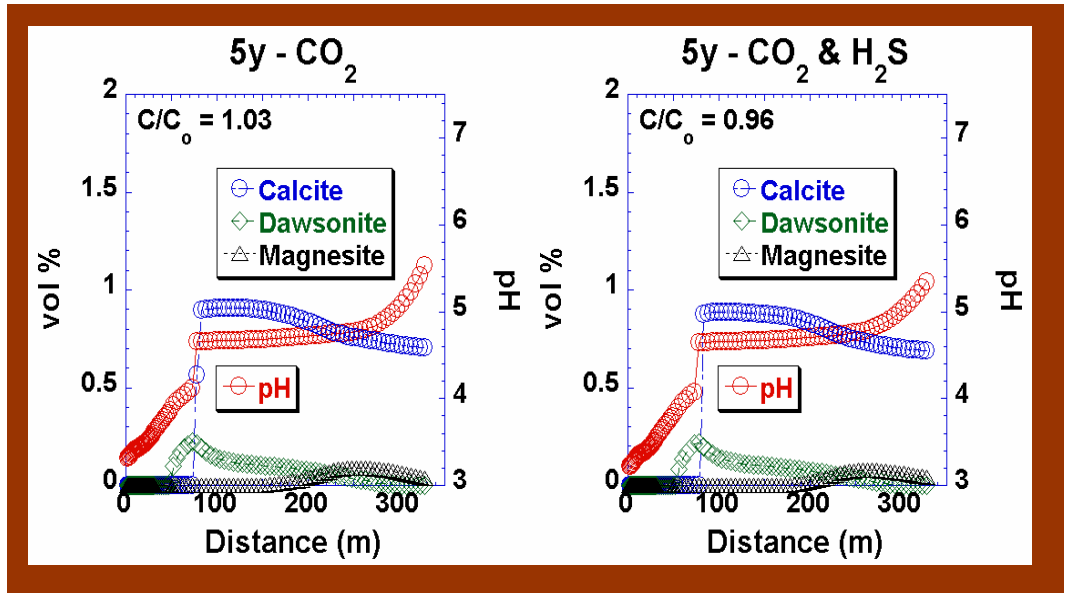
- Curt Oldenburg, Karsten Pruess and Sally Benson, LBNL
- Proof of Concept for CSEGR
  - Properties of CO_2 and CH_4 favor CSEGR
  - Field scale simulations show significant enhanced recovery
  - 5-spot simulations confirm favorable conditions for EGR
  - Economics indicate feasibility



Schematic of CSEGR

Co-Disposal of CO_2, H_2S, NO_2 and SO_2

- Kevin Knauss and Jim Johnson, LLNL
- Co-disposal options
  - Reactive transport simulation capability
  - H_2S has little impact on storage security
  - $H_2S < NO_2 < SO_2$
  - Ready to partner with capture technology



Comparison of geochemical interactions with and without H_2S

Lost Hills CO_2 Migration Monitoring Pilot Study

Lost Hills CO_2 Flood Pilot Test

- Operated by Chevron
- Diatomite formation
- 1500 - 2000 ft deep
- 175,000 std ft^3/day CO_2 injection

Monitoring

- Cross-well seismic
- Cross-well EM
- Single-well seismic
- Tracer development

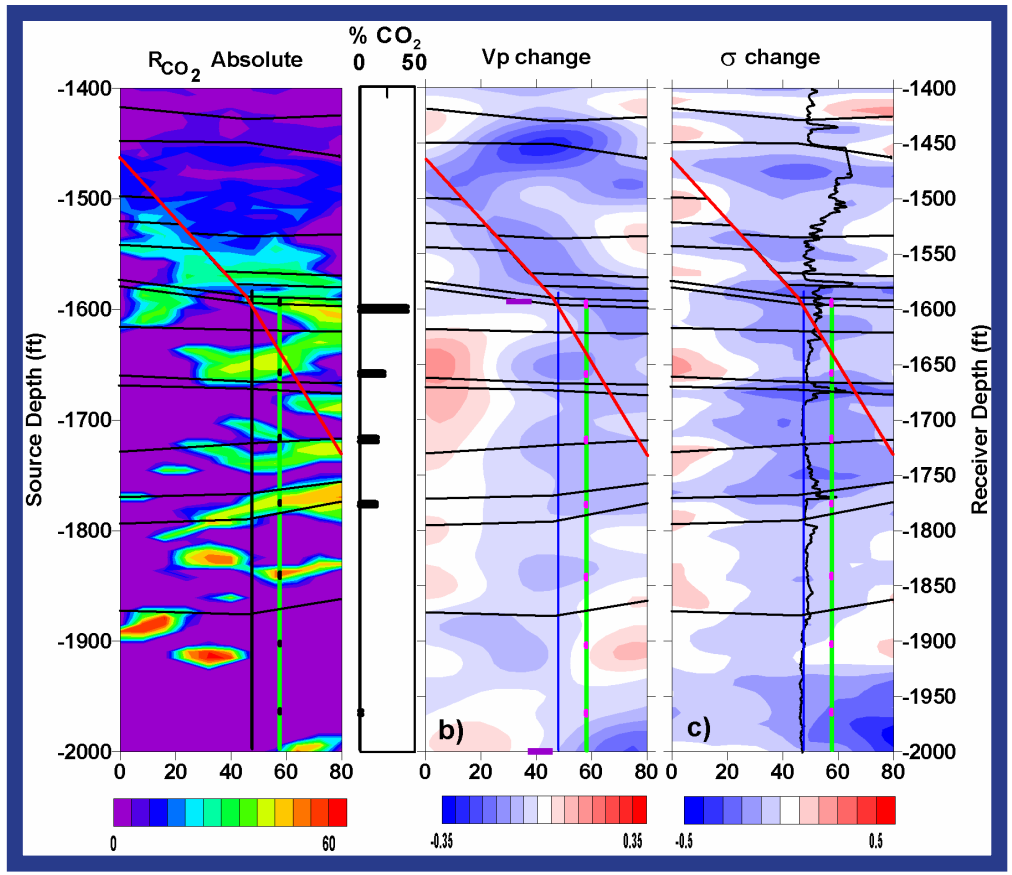
Activities

- Pre-injection baseline
- August 2000, injection initiated
- Post-injection: April, May, July

Cross-Well Seismic Imaging
At Lost Hills Oil Field
In the Central Valley, California

Lost Hills CO_2 Monitoring Project

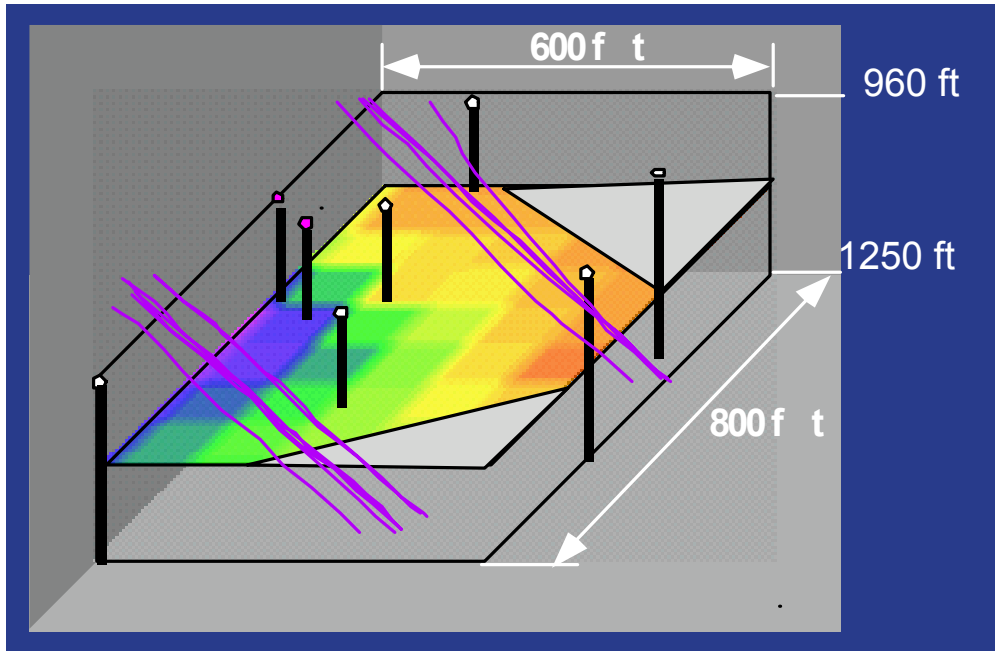
- Mike Hoversten, Ernie Majer, Larry Myer, LBNL
- Monitoring technology demonstration
  - High resolution cross-well seismic and EM imaging
  - Combined seismic and EM interpretation
  - Quantification of CO_2 content
  - Useful for co-optimization and leak detection



High resolution image of injected CO_2 obtained using cross-well seismic and EM imaging

Electrical Resistance Tomography

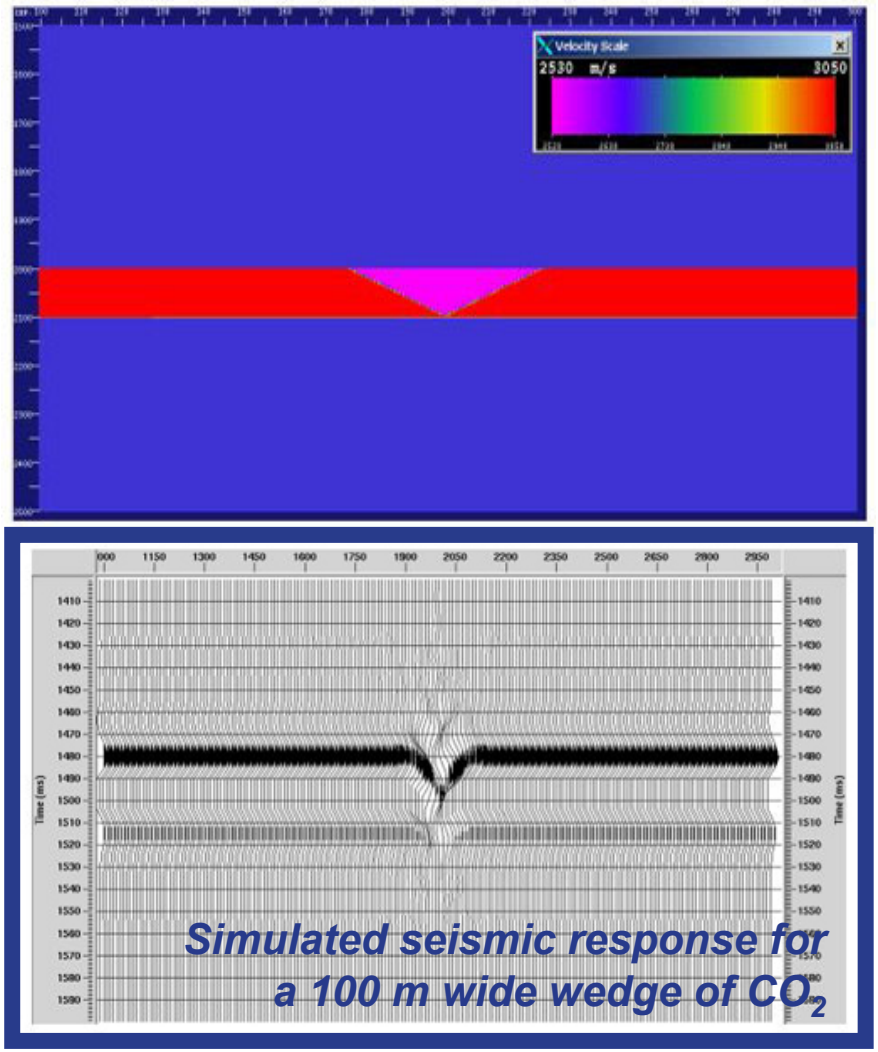
- Robin Newmark and Abe Ramirez, LLNL
- Proof of concept and field demonstration
  - Useful for CO_2 plume detection
  - Low cost monitoring technology using casings as electrodes
  - Simulations demonstrate adequate sensitivity
  - Field demonstration at Vacuum Field underway



Example of electrical resistance tomography using the casings as electrodes

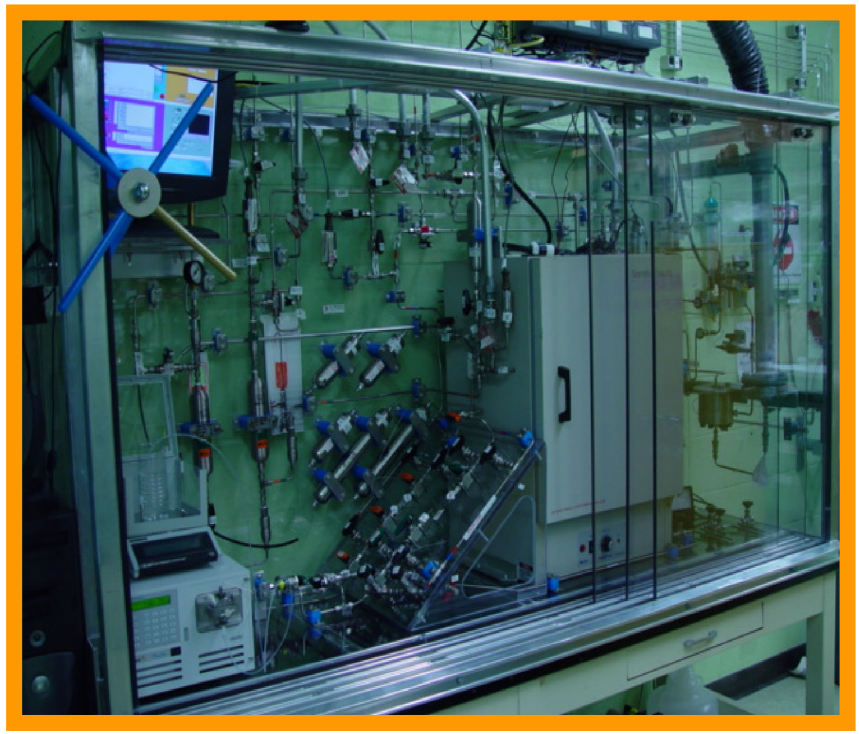
Resolution and Sensitivity of Geophysical Measurements

- Larry Myer, LBNL
- Establish detection levels for seismic monitoring
  - Methodology developed for sensitivity studies
  - Detection limits sensitive to physical properties and geometry of CO_2 plume
  - Optimization of monitoring approaches
  - Feasibility studies for leak detection



Natural and Introduced Tracers for CO_2 Monitoring

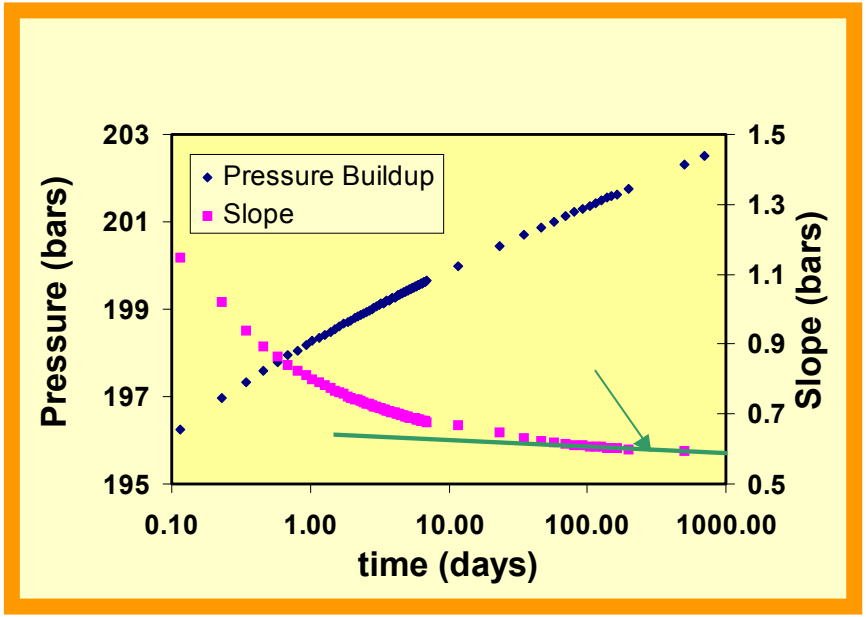
- Dave Cole and Tommy Phelps, ORNL
- Develop tracers for monitoring geologic storage of CO_2
  - Isotopes of C and O for plume ID and geochemical interactions
  - Perfluorocarbon tracers (PFT) for plume ID and dissolution monitoring
  - Field demonstration at Lost Hills for isotopes
  - Laboratory apparatus for testing PFT's



Laboratory test set-up for evaluating tracers

Pressure Build-up in CO_2 Injection Wells

- Sally Benson, LBNL
- Develop new analytical solution for calculating pressure buildup in CO_2 injection wells
  - Quick and easy calculation for pressure buildup in CO_2 injection wells
  - Calculate safe injection rates
  - Design and interpret well tests
  - Multiphase flow properties and front tracking



Pressure buildup calculations from a new analytical solution for CO_2 injection into brine formations

Intercomparison Studies for Simulation for Geologic Storage of CO_2

Comparison of Numerical Simulators for Gas Storage in Coal Beds

Bill Gunter and David Law

Alberta Research Council

5 simulation codes
6 sample problems
Simple to complex problems
Web-site
Study will be concluded this year

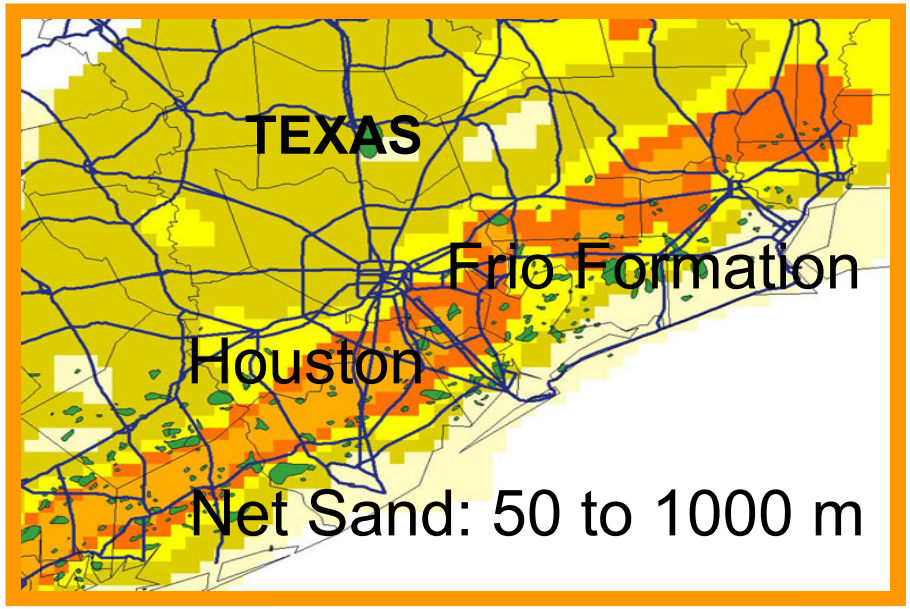
11 Research groups around the world
8 sample problems
2 workshops
Fair to good agreement between codes
Need for accurate thermodynamic data
Web-site and report
Discussion for 2nd round underway

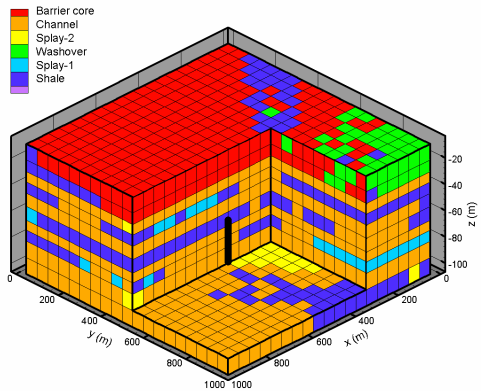
An Intercomparison Study of Simulation Models for Geologic Sequestration Of CO_2

Karsten Pruess and Chin Fu Tsang LBNL

Capacity Assessment Methods

- Christine Doughty, Susan Hovorka and Sally Benson
- Develop reliable methods for estimating storage capacity in brine formations
  - Consider two-phase flow, geometry and heterogeneity
  - Stochastic simulations
  - Define capacity factor
  - New capacity estimates are 5 to 10 times higher that previous estimates

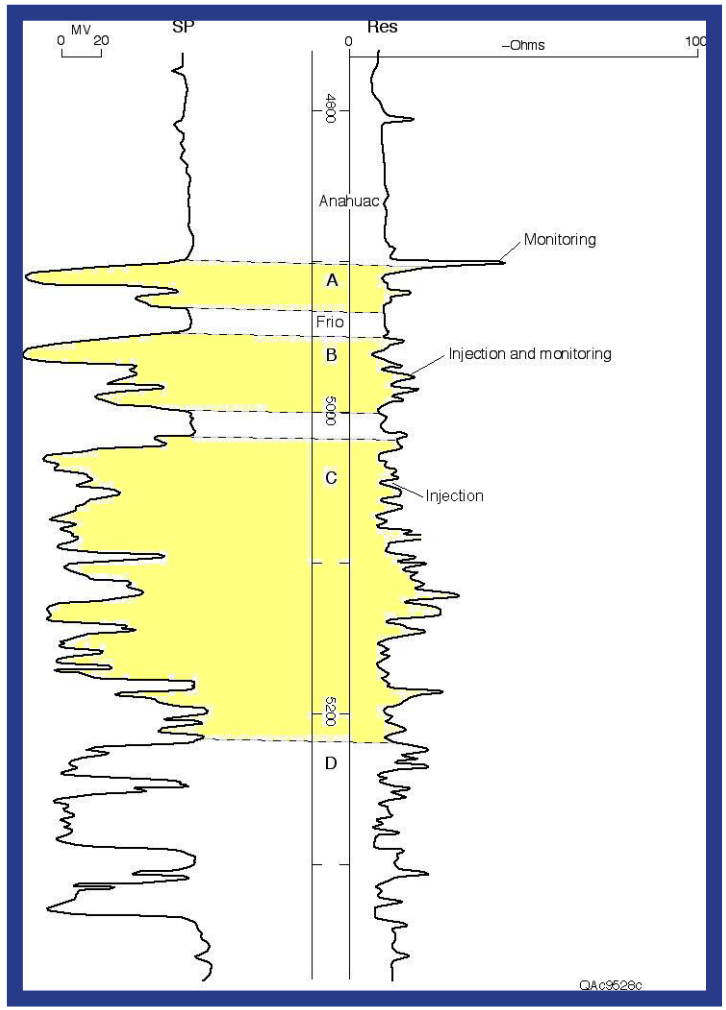




Stochastic realization of the Frio Formation

Frio Brine Formation Pilot Test

- Susan Hovorka and the GEO-SEQ Team
- Demonstrate safe injection of CO_2 and monitoring technology
  - Small-scale test (5000 tonnes CO_2)
  - Extensive monitoring and verification
  - Begin Fall 2003
  - See next talk by Susan Hovorka for more information



Well log showing the injection interval and caprock at the test site

Conclusions

- Significant progress has been made towards all of the overall goals of the GEO-SEQ project
  - Lower the cost of sequestration through co-optimization
  - Decrease risk through better monitoring technology, improved performance assessment models and more reliable capacity assessment
  - Decrease the time to implementation through pilot testing of monitoring technologies and identification of pilot testing opportunities
  - Increase public acceptance by improving the scientific foundations and information
- Frio Formation brine injection pilot beginning this summer
- Future focus for GEO-SEQ: Measurement, Monitoring and Verification